EARLY MIOCENE ROCKY SHORE AND COARSE SEDIMENT FOSSIL COMMUNITIES, KAWAU ISLAND, AUCKLAND

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Abstract. Eighty-four macrofossil taxa (including 43 molluscs, nine echinoids, eight chordates, and three each of barnacles, corals and brachiopods) are recorded from the Kawau Subgroup at Fossil Point, Bostaquet Bay, Kawau Island, north of Auckland city. Nineteen species of foraminifera (shelled Protozoa) are recorded from two microfossil samples from the associated strata. The fossil faunas confirm an early Miocene (Otaian stage) age.

The macrofauna is inferred to contain a mixture from three communities. Nearly half the fauna (e.g. *Sarmaturbo, Haliotis, Cookia, Cellana, Crenostrea,* hermatypic corals, some *in situ),* is derived from a subtidal rocky shore and coarse gravel community that probably lived at 0-20 m depth. Most of the rest of the macrofauna, as well as the foraminiferal microfauna is an *in situ,* inner shelf sand community that lived in a moderately exposed paleobay at inferred depths of 10-30 m. Also present are macrofossils that are inferred to have floated or washed in from the surrounding rocky shoreline, from a nearby estuary and from the nektonic fauna that lived farther out to sea.

PREVIOUS WORK

The geology and stratigraphy of the early Miocene rocks on Kawau Island have been mapped and/or described by Cox (1882), Park (1886), Ferrar (1934), Hopgood (1961), Wood (1976), Hayward & Brook (1984) and Ricketts *et al.* (1989).

Buchanan (1870) recorded six of the more common mollusc genera from the fossil fauna within the sequence at Fossil Point, Bostaquet Bay. Later, Powell (1938) recorded fifteen species of mollusc from Bostaquet Bay, including descriptions of three new species of shallow rocky shore molluscs - two *Haliotis* and one *Cookia.*

GEOLOGY (Fig. 1)

Kawau Island is composed of Permian to Jurassic Waipapa Group greywacke basement unconformably overlain in places by the eroded remnants of an early Miocene transgressive sequence (basal Waitemata Group). This sequence progressively buries an irregular coastal topography of actively eroding greywacke stacks, cliffs and embayed islands (Ricketts *et al.* 1989).

The basal Waitemata Group rocks (Kawau Subgroup, Cape Rodney Formation - Hayward & Brook (1984)) on Kawau Island exhibit different transgressive sequences in different areas or paleobays. Fossil Point in Bostaquet Bay was chosen for this study because

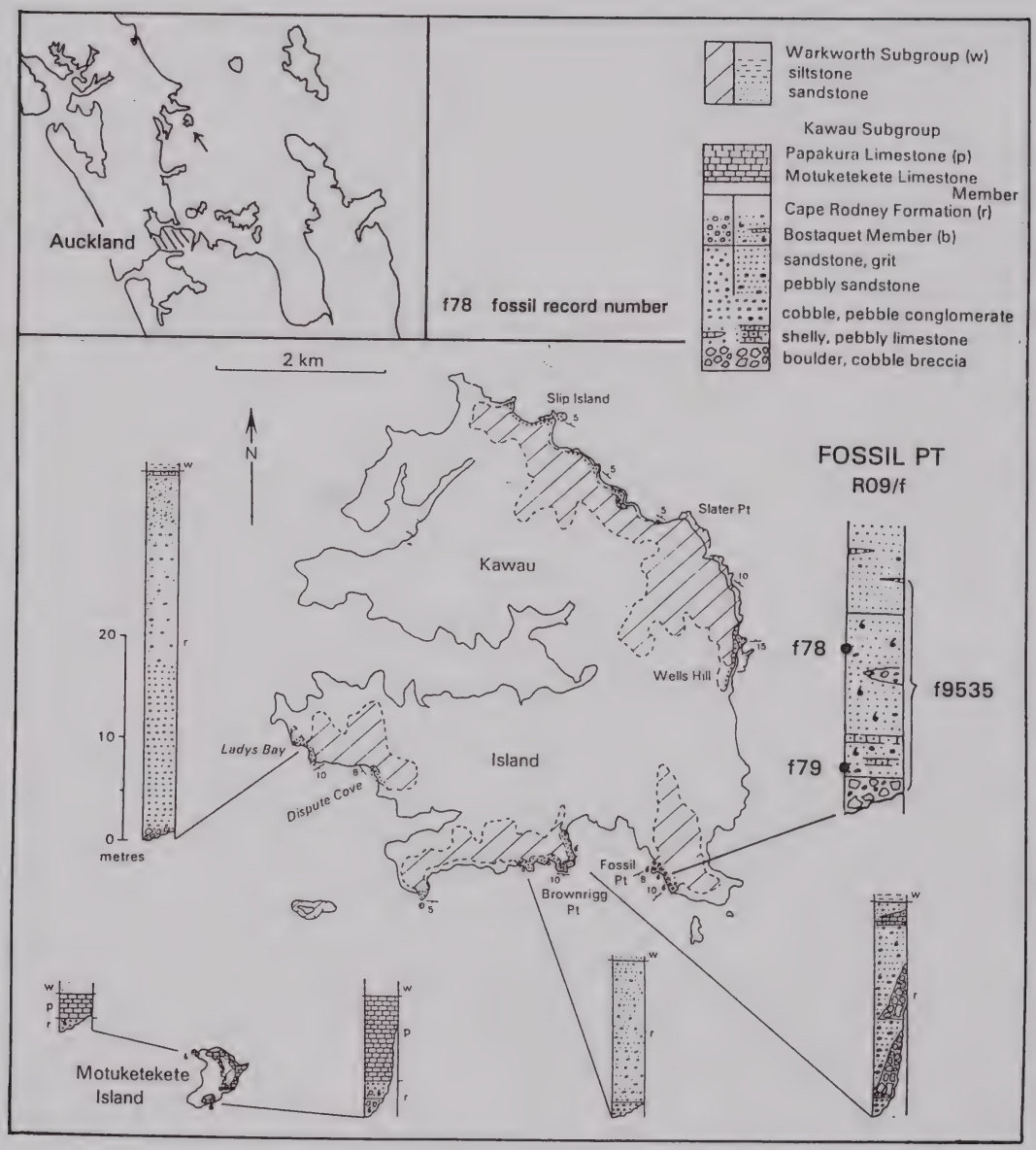


Fig. 1. Geological map of Kawau Island, with stratigraphic column for the early Miocene Kawau Subgroup in eastern Bostaquet Bay (after Hayward & Brook 1984).

of its rich macrofossil content in an uncommon sandy calcareous facies (Bostaquet Member - Hayward & Brook (1984)).

Around Fossil Point, the Kawau Subgroup fills a small paleobay, about 200 m across. Subsequent compaction has produced a shallow syncline within the paleobay, with the 14 m thick sequence sloping up and onto the greywacke on either side. The sequence (Fig. 1)

consists of 1-2 m of calcite-cemented, angular to subrounded, boulder, cobble breccia sitting directly on the greywacke. This is overlain by 2 m of slightly shelly, medium sandstone with cemented bands of shelly, pebbly limestone, which passes up into 10 m of calcareous, shelly, slightly carbonaceous, medium sandstone with rare pebble or cobble horizons. This unit is the local top to the sequence, but elsewhere around Kawau and on nearby Motuketekete Island, the gravelly and sandy Kawau Subgroup sequence is abruptly but conformably overlain by massive mudstone then flysch of the deep water Warkworth Subgroup (Hayward & Brook 1984).

In this paper, we focus on the paleontology of the Bostaquet Member at Fossil Point, Kawau Island. The macrofossil fauna listed here is based on several collecting trips carried out jointly and separately by all the authors between 1991 and 1994, combined with additional records of rarer fossils found by several colleagues or held in the collections of the Auckland Institute and Museum (collected by A.W.B. Powell). In this paper, we provide the first updated published list of the macrofauna since Powell (1938), a foraminiferal species list, and the first interpretation of the paleoenvironment as provided by the fossil faunas.

Fossil Record Numbers are those of the New Zealand Fossil Record File (prefixed by R09). All macrofossils are held in the collections of Auckland Institute and Museum (unless otherwise specified in Appendix 1) and all microfossils are held by the Institute of Geological and Nuclear Sciences, Lower Hutt.

MACROFAUNA

All collected taxa are listed in Appendix 1. The paleontological and paleoenvironmental assessment that follows is largely based on the known ecology of genera living today and of modern species most closely related morphologically to these fossils.

The diverse fossil macrofauna collected from the calcareous sandstone facies unit at Bostaquet Bay consists of many broken and disarticulated specimens. Minor pre-burial transport probably accounts for both breakage and disarticulation. Calcium carbonate recrystallization is present in all fossils found here. Prolonged leaching and weathering of specimens has occurred as the coastal exposures are not subject to rapid erosion. Structural and compactional deformation of the rocks has compressed some fossil specimens, flattening gastropods and distorting bivalves.

Analysis of the macrofossil fauna from Fossil Point (R09/f9539) has enabled us to recognise that it is composed of elements from three communities. Each is discussed seperately below.

SUBTIDAL ROCKY SHORE AND COARSE GRAVEL COMMUNITY, 0-20 m (Fig. 2)

Nearly half (29 species) the Fossil Point fossil assemblage is the remains of organisms that are inferred to have lived in a shallow subtidal rocky reef habitat (c. 0-20 m). Epifaunal rocky reef inhabiting gastropods include the limpet *Cellana,* the large turbin *Sarmaturbo,* the carnivorous *Conus* and *Conilithes* and, living beneath stones and ledges browsing upon coralline and other algae, *Haliotis* and *Cookia.*

Fig. 2. Schematic drawing of the *in situ* intertidal and shallow subtidal rock and coarse gravel community (0-5m) at Fossil Point, Bostaquet Bay, Kawau Island. Al= *Alveopora polycanthus;* Ar= *Armatobalanus motuketeketeensis;* Ce= *Cellana thomsoni;* Ck= *Cookia kawauensis;* Cr= *Crenostrea gittosina;* Ct= *Conus* (sensu lato) *thorae;* Go= *Goniocidaris pusilla;* Hf= *Haliotis (Sulculus) flemingi;* He= *Hemiplax* sp.; Hi= *Histocidaris mackayi;* Hw= *Haliotis (Notohaliotis) waitemataensis;* Le= *Leptastrea* sp.; Mg= *Magasella neozelandica;* No= *Notosaria antipoda;* Oc= *Oculina virgosa;* Pe= *Perna tetleyi;* Pt= *Pteria oneroaensis;* Py= *Phyllacanthus titan;* S= *Sargus laticonus;* Sa= *Sarmaturbo superbus;* Ta= *Tasmanobalanus grantmackiei;* Te= *Terebratulina suessi.* No scale implied. (Hw, after Beu *et al.* 1990).

In the same community, nestling in cracks, under ledges, or in cavities lived other algal grazers such as cidarid echinoids. Interambulacral plates and spines show that *Goniocidaris, Histocidaris* and the large subtropical *Phyllacanthus* lived in this community. Complete tests of undescribed species of Australian tropical genera now extinct to New Zealand include *Arbia, Phymechinus, Steroepedina* and *Schizechinus.*

Sheets of the hermatypic corals *Alveopora* and *Leptastrea* grew on coarse, gravelly substrate or rocky reefs. Some of the coral sheets occur in growth position on the basal greywacke substrate and in the gravels just above it, at the south end of the Fossil Point outcrop of Kawau Subgroup. The ahermatypic coral *Oculina,* usually found living today somewhat deeper than 15 m, is also present in this assemblage.

The sessile, filter-feeding brachiopods *Magasella, Notosaria,* and *Terebratulina* are inferred to have occupied this hard substrate, either beneath rocks or under overhangs. Also

present were the sedentary byssate bivalves *Perna* and *Pteria* along with the barnacles *Armatobalanus, Notobalanus* and *Tasmanobalanus* which lived attached to the rocky substrate or mollusc shells. A chela of the crab *Hemiplax* is the only evidence of any decapod Crustacea. This crab probably resided in narrow crevices or beneath stones.

Beak-like teeth found at this site belonged to a representative of the Scaridae family, *Sargus,* a parrot fish that is inferred to have lived in this community and probably included coral polyps in its diet. Parrot fish live today at depths of 0-50 m in tropical and subtropical seas.

Specimens of the large oyster *Crenostrea* are common. Many are bored by worms and sponges. The borings of pholad molluscs (ichnofossil genus *Trypanites)* occur in the greywacke bedrock and cobbles but no shells were seen. Lumps of enveloping, laminate, coralline algae (rhodoliths) are also common. Various indeterminate Bryozoa encrust empty mollusc shells or pebbles. The fauna described above probably lived amongst hydroids, seaweeds, annelids, sponges and tunicates, none of which is usually fossilised.

The paleoenvironment in which this community lived is inferred to have been just offshore from a moderately exposed, rocky and bouldery coastline with paleo-water depths of 0-20 m. It was probably exposed to oceanic swell and periodically high wave action.

SHALLOW INNER SHELF SAND COMMUNITY, 10-30 m (Fig. 3)

At least 30 species in the Fossil Point macrofauna are inferred to have lived in or on soft sandy sediment at inner shelf depths. The fauna is dominated numerically by shallow burrowing, suspension-feeding bivalves such as *Dosinia.*

The byssate, pectinid *Chlamys* may have lived attached to the underside of rocks or enmeshed in sponges. *Lima, Mesopeplum* and extinct *Lentipecten* were freely mobile bivalves in this biotope, like the modern New Zealand *L. colorata zelandia* and *M. convexum.* An important element was the large lucinid *Miltha,* which typically inhabits shellbeds in soft, shallow water substrates such as this. The lucinid, *Divaricella huttoniana* probably also lived in this community, as it does in New Zealand today (Powell 1979). Another large, inflated, thin-shelled, filter-feeding bivalve resident in this community was the New Zealand endemic genus *Hedecardium.* The golden oyster, *Anomia* is also inferred to have lived here.

Many infaunal deposit-feeding bivalves are present, including the long divergent-siphonate genera *"Tellina"* and *Bartrumia,* the fragile, thin-shelled *Offadesma* and the relatively large, elongate carditid *Megacardita* and the glycymerid *Tucetona.* Like the extant Australian species which are primarily inner shelf dwellers (Beu *et al.* 1990), the thick-shelled *Eucrassatella* occuring in this fossil assemblage may have been under constant threat of surf-churned eviction.

Of the gastropods, the ciliary deposit-feeding turritellids *Maoricolpus* and *Tropicolpus* were prominent members of this community, together with the circular-saw shell *Astraea,* specimens of which are commonly dredged on the inner-mid shelf all round New Zealand today (Powell 1979). *Struthiolaria* was another infaunal ciliary-feeding gastropod in this community. The deposit-feeding infaunal scaphopods *Antalis, Dentalium* and *Fissidentalium,* are also inferred to have lived in this community.

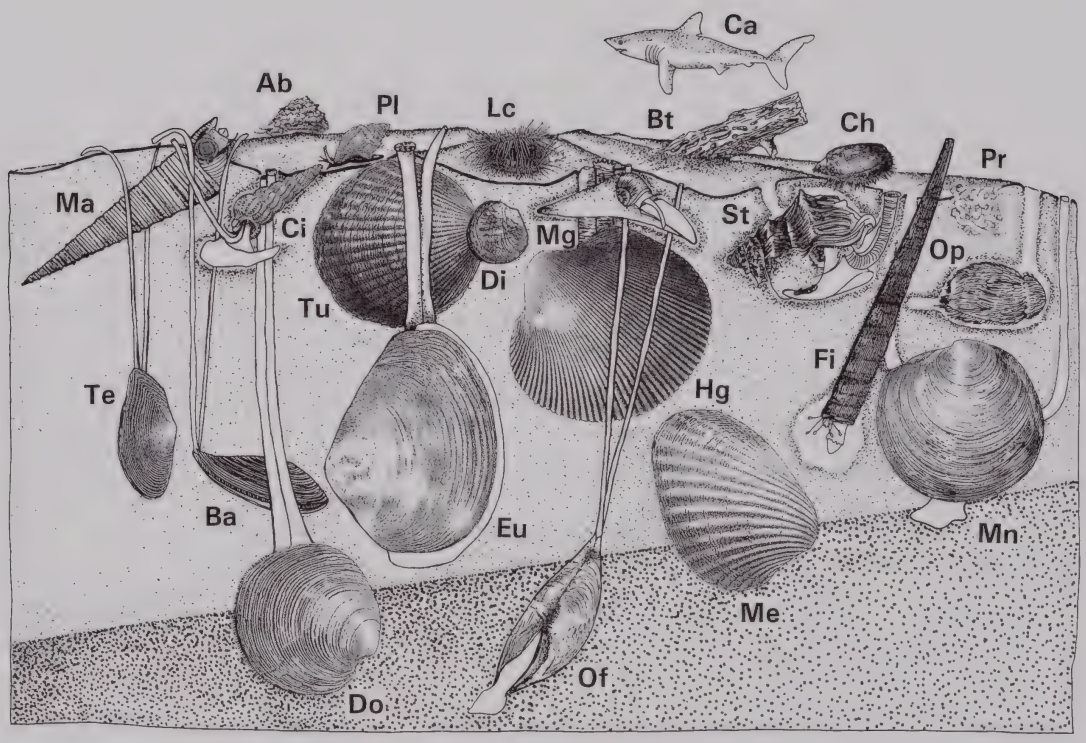


Fig. 3. Schematic drawing of the *in situ* shallow subtidal sand community (0-20 m) at Fossil Point, Bostaquet Bay, Kawau Island. Ab= *Astraea bicarinata;* Ba= *Bartrumia oneroaensis;* Bt= *Bankia turneri;* Ca= *Carcharias taurus;* Ch= *Chlamys fischeri;* Ci= *Cirsotrema firmatum;* Di= *Divaricella (Divalucina) huttoniana;* Do= *Dosinia (Raina) bensoni;* Eu= *Eucrassatella ampla;* Fi= *Fissidentalium* n.sp; Hg= *Hedecardium (Titanocardium) greyi;* Lc= *Lima colorata;* Ma= *Maoricolpus waitemataensis;* Me= *Megacardita squadronensis;* Mg= *Magnatica (Spelaenacca) waitemataensis;* Mn= *Miltha neozelanica;* Of= *Offadesma angasi;* Op= *Opissaster rotundatus;* Pl= *Paracominia lignaria;* Pr= *Protula* cf. *turbularia;* St= *Struthiolaria lawsi;* Te= *"Tellina" hesterna;* Tu= *Tucetona aucklandica.* No scale implied. (Ab, Ci, Do, Eu, Fi, Hg, Me, Mi, Pl, Te, Tu after Beu *et al.* 1990; Ma, Mg, Op, St after Morton & Miller 1968).

The limpet-like gastropod *Zegalerus* probably attached itself to empty bivalve shells or rocks. The globular, infaunal carnivore *Magnatica (Spelaenacca)* would have preyed on the burrowing molluscs present by drilling holes and inserting a fine proboscis to draw out the flesh. *Cirsotrema* probably lived suctorially upon anemones as does the similar recent epitoniid, *Epitonium jukesianum* (Morton & Miller 1968). The tropical to subtropical gastropod *Morum (Oniscidia)* would have been an active burrowing predator. Extant species of the turrid *Borsonia* are bathyal, but fossil species, as found here, are thought to have mostly lived in shallower water.

The free or attached serpulid *Protula,* was found in living orientation partly buried in sediment with its erect anterior tubes protruding. Like the recent New Zealand echinoderm

Echinocardium, the spatangoid *Opissaster* and the extant Australian *Echinoneus* were probably infaunal deposit-feeders in this community.

Carcharias, like the white-pointer shark of today, probably cruised inshore from time to time in search of prey or carrion. Ichnofossils are common in the sandstone and include the complex grazing traces of *Nereites*, Domichnia structures such as *Skolithos* and Repichnia *Cruziana* structures.

This community is inferred to have lived in slightly shelly, medium sand in a moderately exposed location at shallow inner shelf depths of about 10-30 m.

NEKTONIC AND OTHER EXOTIC FAUNA (Fig. 4)

Teeth, bones and floating shells are the scattered evidence of the nektonic fauna that lived in oceanic water beyond the immediate vicinity of the fossil locality. A possible turtle bone and the rib of an indeterminate small cetacean confirm the presence of these vertebrates in this domain.

An isolated mammalian tooth was also discovered at this site. Dr R.E. Fordyce (pers. comm. 18 April 1994) states that it "is an isolated cheek-tooth from a cetacean ... This tooth is a close match to some Oligocene-early Miocene specimens from New Zealand and from the USA which appear to be archaic heterodont mysticetes - Suborder Mysticeti ... but at present I cannot completely rule out that it is an archaic odontocete (Suborder Odontoceti) or possibly a relict archaeocete (Suborder Archaeoceti) ... the tooth is probably a lower right molar equivalent ... The lack of roots ... suggests that the fossil may be a deciduous (milk) tooth." Fossil teeth with slender lateral cusps from the cosmopolitan sand shark *Odontapsis* are also present, together with a tooth from a species of *Isurus* - a fast swimming, large (6 m) mackeral shark.

A small uncrushed, mature specimen of the nautiloid *Aturia* was found with unusually good preservation (Fig. 7). Because of internal gas-filled chambers, dead cephalopod shells float well at the sea surface and may travel great distances in this manner. Well-preserved shells of nautiloids occur over a very much wider area than that occupied by living specimens (Beu 1973). Thus this fossil *Aturia* has probably floated in from its offshore community, maybe hundreds of kilometres away.

Much carbonaceous material in the form of fossil wood and leaves occurs in the Fossil Point sandstone. The wood is probably sunk flotsam originating from nearby land. Some pieces are bored with long, cylindrical burrows c. 5 mm wide going obliquely into the wood then turning to follow the grain. Tunnels are coated with a thin layer of calcium carbonate, and in places much of the wood has decayed and all that remains are the shelly plates and fulcra of the teredo (*Bankia)* and the calcareous tunnel linings.

Fossil leaves of *Laurophyllum, Nothofagus* and *?Metrosideros* are from either marginal estuarine or coastal cliff trees on nearby land. The leaves have washed into the sea and when waterlogged, sunk to the bottom and have been buried by sand. The carnivorous gastropod *Paracominia* and deposit feeder *Pyrazus* may also be transported elements from a sheltered, nearby estuarine environment.

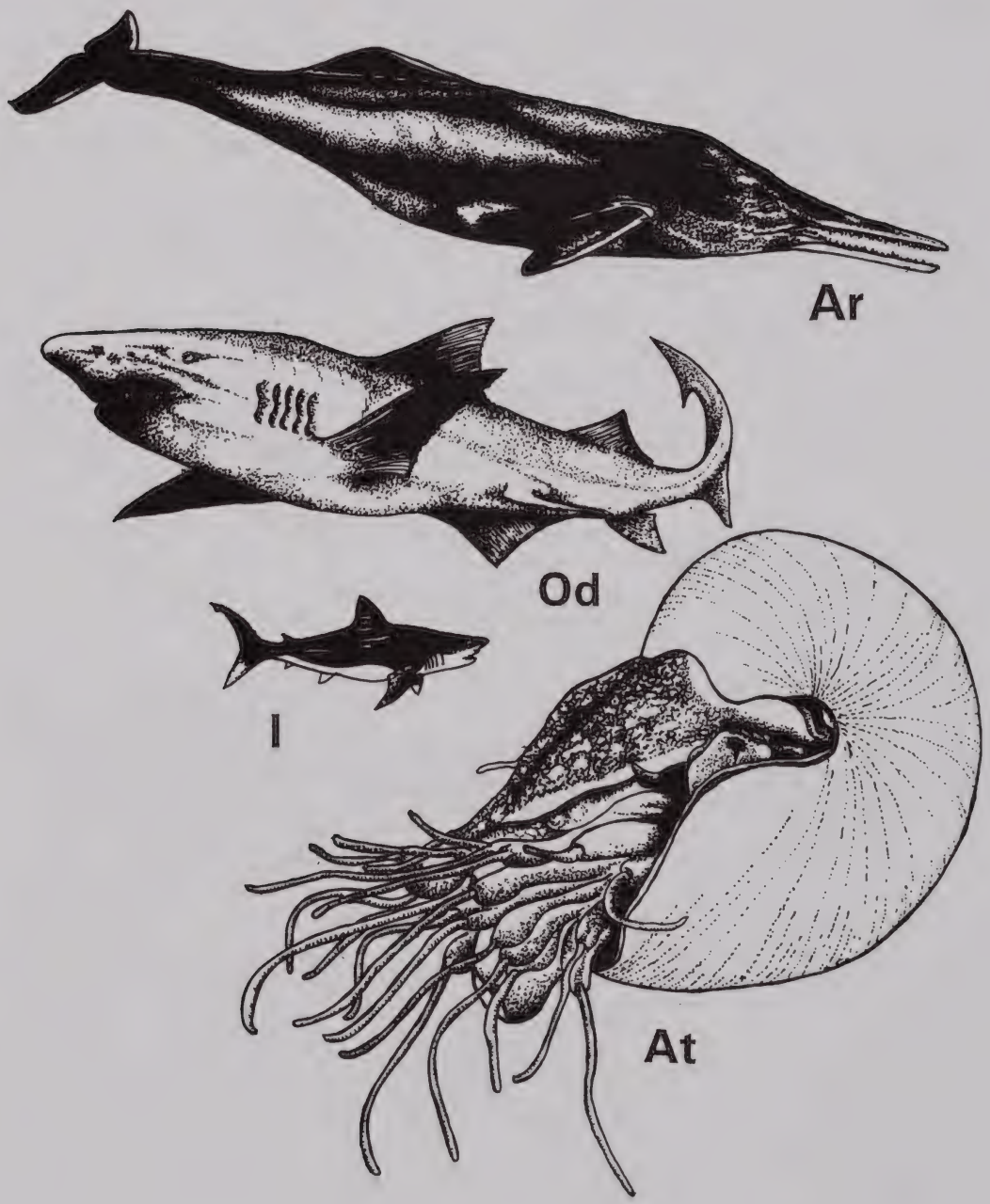


Fig. 4. Schematic drawing of the nektonic fauna transported in to the fossil assemblage at Fossil Point, Bostaquet Bay, Kawau Island. Ar= archaic cetacean; At= *Aturia cubaensis;* I= *Isurus desori;* Od= *Odontapsis elegans.* No scale implied.

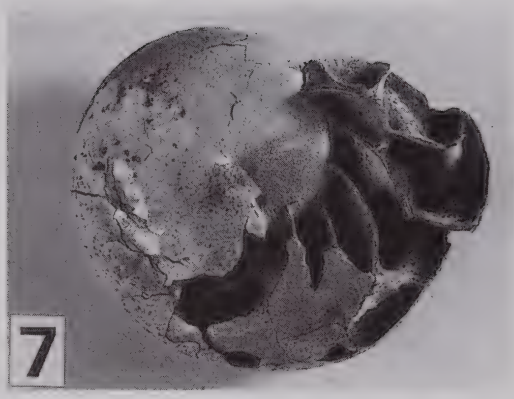
RARE OR UNUSUAL TAXA

The Fossil Point, Kawau Island fossil fauna contains many unusual shallow-water molluscs derived from a seldom preserved early Miocene rocky shore community. Faunal elements are similar to those identified from shallow, Oligocene rocky shore facies at Mt. Luxmore, Fiordland (Lee *et al.* 1983), Castle Hill Basin and Mason River, North Canterbury (Beu *et al.* 1990), and in the similar early Miocene basal Waitemata facies on Waiheke Island (Powell 1938). Some of these molluscs present in Fossil Point fauna are *Pteria oneroaensis, Miltha neozelanica, Bartrumia oneroaensis, Dosinia (Raina) bensoni, Offadesma angasi, Sarmaturbo superbus, Maoricolpus waitematensis, Tropicolpus tetleyi, T. (Amplicolpus) gittosinus, Struthiolaria lawsi* and *Morum (Oniscidia) harpaforme.* Fossil Point is the type locality of the rare species *Haliotis (Notohaliotis) waitemataensis, H. (Sulculus) flemingi* and *Cookia kawauensis.*

At Fossil Point the largest *in situ* heads or sheets (1.2 m x 0.6 m) of reef corals (Fig. 5) so far recorded in New Zealand (cf. Hayward & Brook 1981) are present.

Other unusual records for the early Miocene of New Zealand are the tooth of a large archaic cetacean (Fig. 6), the rib of a small fossil cetacean and a possible turtle bone. Also present are apparently undescribed species of the echinoids *Arbia, Phymechinus, Steroepedina, Schizechinus* and *Echinoneus.*

Fig. 5. Float boulder of *Alveopora* coral sheet (AK84700) from Fossil Point, Kawau Island. Length = 28 cm.



Figs 6-7. Specimens from Fossil Point, Kawau Island. 6. Archaic cetacean tooth (AK87193) showing labial detail. Width = 3.2 cm. 7. *Aturia cubaensis* (AK87192) showing excellent state of preservation. Diameter = 4.5 cm.

MICROFAUNA

Two samples of finer-grained rock (medium sandstone) from within the Fossil Point sequence (R09/f78, f79) were disaggregated and a quantitative pick of 100 benthic foraminifera was made, identified and counted (Appendix 2). Both produced moderately rich, poorly preserved, recrystallised foraminiferal faunas. They contain low planktic foraminiferal numbers (1-2%), which indicate nearshore neritic waters overhead.

The benthic faunas of both samples are remarkably similar and are dominated by *Elphidium gibsoni* and robust *Amphistegina aucklandica,* with subdominant *Cibicides mediocris, C. temperatus* and *Gaudryina convexa.* Today large *Amphistegina, Elphidium* and *Gaudryina* are dominant members of foraminiferal faunas in high energy, coarse sediment at shallow inner shelf depths with normal salinity in subtropical areas. *Cibicides* has a wider environmental tolerance but does occur with these other three genera. Other species present in the fossil faunas that are considered to be inner shelf-restricted are *Cribrorotalia ornatissimum* and *Quasibolivinella finlayi* (Hayward 1986). The total fauna is consistent with a paleoenvironment on an exposed coast at shallow inner shelf depths (2-30 m). This is similar to association C (*Cribrorotalia ornatissimum - Elphidium gibsoni - Cibicides mediocris)* from the early Miocene basal Waitemata sequence on Waiheke Island (Hayward & Brook 1994).

AGE

MACROFAUNAL EVIDENCE

The bivalve genera *Bartrumia* and *Perna* make their first known appearance in New Zealand in the Otaian stage of the early Miocene, as do the species *Lima colorata, Lentipecten* n.sp. aff. *hochstetteri* and the cephalopod *Aturia cubaensis.* The bivalves *Megacardita* and *Lentipecten hochstetteri* (sensu stricto), have their last known appearance in the Otaian. The presence of the gastropod species *Tropicolpus (Amplicolpus) gittosinus, Tropicolpus tetleyi, Sarmaturbo superbus,* and *Struthiolaria lawsi,* which are known only from the Otaian, confirms this early Miocene age.

MICROFAUNAL EVIDENCE

The two shallow water foraminiferal faunas from Fossil Point contain no taxa that are stage specific for determining the age of the sequence. Occasional rare foraminifera in similar basal Waitemata (Kawau Subgroup) strata nearby on Kawau and Motuketekete Islands and subsurface at Orewa provide a fairly accurate assessment of the age of the Fossil Point sequence. The presence in these nearby sections of *Ehrenbergina marwicki* (Otaian-Altonian) on Motuketekete (R09/f74), *Catapsydrax dissimilis* (Duntroonian-Otaian) on Kawau Island (R09/f68, f76) and Motuketekete Island (R09/f74), and *Haeuslerella hectori* (Waitakian-Otaian) in the Orewa Drillhole (R10/f13, cuttings 825-826.9 m) indicate an Otaian (early Miocene) age, which is the accepted age for all of the Kawau and overlying Warkworth Subgroups in the Waitemata Group (Hayward & Brook 1984, Hayward 1993).

The combined macrofaunal and microfaunal evidence gives an early Miocene, Otaian age (c. 22-19 million years old).

PALEOENVIRONMENT AND PALEOGEOGRAPHY

In the Fossil Point sequence, the basal 1-2 m of greywacke breccia contains macrofossils (e.g. *Sarmaturbo, Haliotis, Crenostrea,* hermatypic corals *in situ*) that belong entirely to our "subtidal rocky shore and coarse gravel community" (described earlier). From this we infer that the basal breccia accumulated as cobbly gravel in 0-20 m depths around the moderately exposed, rocky coast of a paleobay.

The overlying 12 m of slightly shelly, medium sandstone that fills the paleobay at Fossil Point contains a foraminiferal microfauna that lived in sand on an exposed coast at shallow inner shelf depths of about 2-30 m. Over half the macrofauna in the sandstone is inferred to have lived in our "shallow inner shelf sand community" in a moderately exposed location at similar depths of about 10-30 m. We conclude that these faunas represent the *in situ* biota and that the sandstone accumulated in this environment. The sandstone also contains substantial fossil material from our "rocky shore and coarse gravel community" that probably washed in from the surrounding coastline of the bay. Other identifiable elements in the sandstone macrofossil assemblage include members of our "nektonic fauna" that are inferred to have floated in from farther out to sea, and leaves and estuarine snails that must have washed in from nearby land.

Within the 12 m of sandstone there is no detectable change in the fossil fauna, except that it is less abundant in the upper parts. It presumably accumulated during a period of sinking with sediment accumulation rate keeping pace with the subsidence.

Other early Miocene Kawau Subgroup sequences on Kawau Island and elsewhere, indicate that the Fossil Point sequence documents just a short interval within a long period of major subsidence, in the order of 1-2 km, that formed the Waitemata Basin (Ricketts *et al.* 1989, Hayward 1993). The Fossil Point sequence records some of the earliest subsidence, when nearby land areas or islands had not yet subsided beneath the waves and their erosion provided the gravel and sand that accumulated in this ancient bay preserving the fossil assemblages within it. Once all local land areas had been submerged, this area became starved of sediment and there followed a long period with little or no sediment accumulation, until the

area had subsided to mid bathyal depths and sand-bearing turbidites from the northwest could flow across the basin floor to reach it (Ricketts *et al.* 1989, Hayward 1993).

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APPENDIX 1. Systematic list of macrofauna from Fossil Point, Bostaquet Bay, Kawau Island, Hauraki Gulf. Taxonomy follows Beu *et al.* (1990) for Mollusca; Dawson (1990) for brachiopods; Foster (1978) and Buckeridge (1983) for barnacles; Squires (1958, 1962) for coelenterates; Feldmann & Keyes (1992) for decapod Crustacea; Chapman (1918) and Vickers-Rich *et al.* (1991) for chondrichthyans; Henderson (1975) for spatangoid echinoids; Fell (1954) for cidarid echinoids; Fleming (1971) and Hayward (1977) for Polychaeta; E. Fordyce (pers. comm.) for Cetacea; and Pole (1993a, 1993b), and E. Cameron and R. Gardner (pers. comm.) for vascular plants. Specimens are located in the Auckland Institute and Museum collection unless stated otherwise: GC = Glen Carter; ME = Michael Eagle. Species numbers are: A = abundant; C = common; U = uncommon.

	BIVALVIA		
GLYCYMERIDIDAE	*Tucetona aucklandica* (Powell, 1938)	GC	C
PTERIIDAE	*Pteria oneroaensis* (Powell & Bartrum, 1929)		U
MYTILIDAE	*Perna tetleyi* (Powell & Bartrum, 1929)		U
PECTINIDAE	*Mesopeplum burnetti* (Zittel, 1864)	ME	C
	Mesopeplum costatostriatum (Marshall, 1918)	ME	C
	Lentipecten hochstetteri (Zittel, 1864)		U
	Lentipecten n. sp. aff. hochstetteri (Zittel, 1864)	ME	U
	Chlamys fischeri (Zittel, 1864)		C
ANOMIIDAE	*Anomia trigonopsis* Hutton, 1877	ME	C
LIMIDAE	*Lima colorata* Hutton, 1873		C
GRYPHAEIDAE	*Crenostrea gittosina* (Powell & Bartrum, 1929)		A
LUCINIDAE	*Divaricella (Divalucina) huttoniana* (Vanatta, 1901)		C
	Miltha neozelanica Marshall & Murdoch, 1921	GC	U
CARDITIDAE	*Megacardita squadronensis* (Powell, 1938)		U
CRASSATELLIDAE	*Eucrassatella ampla* (Zittel, 1864)		A
CARDIIDAE	*Hedecardium (Titanocardium) greyi* (Hutton, 1873)		U
TELLINIDAE	*"Tellina" hesterna* (Powell & Bartrum, 1929)		C
	Bartrumia oneroaensis (Powell & Bartrum, 1929)		U
VENERIDAE	*Dosinia (Raina) bensoni* Marwick, 1927		A
TEREDINIDAE	*Bankia turneri* Powell & Bartrum, 1929		A
PERIPLOMATIDAE	*Offadesma angasi* (Crosse & Fischer, 1864)	ME	U
	GASTROPODA		
NACELLIDAE	*Cellana thomsoni* Powell & Bartrum, 1929	ME	U
HALIOTIDAE	*Haliotis (Sulculus) flemingi* Powell, 1938		U
	Haliotis (Notohaliotis) waitemataensis Powell, 1938		U
TURBINIDAE	*Astraea bicarinata* Suter, 1917		U
	Cookia kawauensis Powell, 1938		U
	Sarmaturbo superbus (Zittel, 1864)		A
POTAMIDIDAE	*Pyrazus consobrinus* Powell & Bartrum, 1929	ME	U
TURRITELLIDAE	*Maoricolpus waitemataensis* (Powell & Bartrum, 1929)		A
	Tropicolpus tetleyi (Powell & Bartrum, 1929)		U
	Tropicolpus (Amplicolpus) gittosinus (Powell & Bartrum, 1929)		U
TURRIDAE	*Borsonia* n.sp.		U
STRUTHIOLARIDAE	*Struthiolaria lawsi* Powell & Bartrum, 1929		U
CALYPTRAEIDAE	*Zegalerus perampla* (Powell & Bartrum, 1929)		U

NATICIDAE	*Magnatica (Spelaenacca) waitemataensis* (Powell, 1938)	GC	U
EPITONIIDAE	*Cirsotrema firmatum* Laws, 1939		U
BUCCINIDAE	*Paracominia lignaria* (Powell & Bartrum, 1929)		U
HARPIDAE	*Morum (Oniscidia) harpaforme* Powell & Bartrum, 1929		U
CONIDAE	*Conilithes wollastoni* Maxwell, 1978	ME	U
	Conus thorae Finlay, 1926	ME	U
	SCAPHOPODA		
DENTALIIDAE	*Antalis pareoraensis* (Pilsbry & Sharp, 1897)		U
	Dentalium mantelli Zittel, 1864		U
	Fissidentalium n.sp.		U
	CEPHALOPODA		
ATURIIDAE	*Aturia cubaensis* (Lea, 1841)		U
	BRYOZOA		
	gen. & sp. indet.		A
	BRACHIOPODA		
CANCELLOTHYRIDIDAE	*Terebratulina suessi* (Hutton, 1873)		C
DALLINIDAE	*Magasella neozelandica* (von Ihering, 1903)		A
HEMITHYRIDIDAE	*Notosaria antipoda* (Thomson, 1918)		A
	POLYCHAETA		
SERPULIDAE	*Protula* cf. *turbularia* (Montagu, 1803)	GC	C
	gen. & sp. indet.		C
	ECHINOIDEA		
CIDARIDAE	*Phyllacanthus titan* Fell, 1954		C
	Goniocidaris pusilla Fell, 1954		U
	Histocidaris mackayi Fell, 1954	ME	U
ARBACIOIDA	*Arbia* n.sp.	ME	C
STOMECHINIDAE	*Phymechinus* n.sp.	ME	U
PEDINOIDA	*Steroepedina* n.sp.	ME	U
TOXOPNEUSTIDAE	*Schizechinus* n.sp.	ME	U
SPATANGOIDEA	*Opissaster rotundatus* (Zittel, 1864)		U
ECHINONEIDAE	*Echinoneus* n.sp.	ME	U
	CIRRIPPEDIA		
ARCHAEOBALANIDAE	*Notobalanus vestitus* (Darwin, 1854)		C
	Armatobalanus motuketeketeensis Buckeridge, 1983	GC	U
	Tasmanobalanus grantmackiei Buckeridge, 1983	ME	U
	DECAPODA		
OCYPODIDAE	*Hemiplax* sp.	ME	U
	gen. & sp. indet. (chela)	GC	U
	COELENTERATA		
PORITIDAE	*Alveopora polycanthus* Reuss, 1867		C

FAVIIDAE	*Leptastrea cf. transversa* Klunzinger, 1879		C
OCULINIDAE	*Oculina virgosa* Squires, 1958		U
	CHONDRICHTHYES		
ODONTASPIDIDAE	*Odontaspis elegans* Agassiz, 1843	ME	U
CARCHARIIDAE	*Carcharias taurus* Rafinesque, 1810	ME	U
LAMNIDAE	*Isurus desori* (Agassiz, 1843)	ME	U
	TELEOSTEI		
	gen. & sp. indet. (scale)	GC	U
SCARIDAE	*Sargus laticonus* Davis, 1888	ME	U
	CETACEA		
	gen. & sp. indet. (tooth)		U
	gen. & sp. indet. (rib)	GC	U
	REPTILIA		
	gen. & sp. indet. (?turtle bone)		U
	ICHNOFOSSILS		
	Nereites sp. indet.		C
	Skolithos sp. indet.		C
	Cruziana sp. indet.		C
	ALGAE		
RHODOPHYCEAE	Rhodolith sp. indet.		A
	TERRESTRIAL FLORA		
LAURACEAE	*Laurophyllum longfordiensis* (Holden, 1982)	GC	U
FAGACEAE	*Nothofagus* sp.	GC	U
MYRTACEAE	*?Metrosideros* sp.		U

APPENDIX 2. List of foraminifera obtained from Fossil Point, Kawau Island. Numbers are abundances (%) in each sample. Taxonomy follows Hornibrook *et al.* (1989) and Hayward & Buzas (1979).

	R09/f79	R09/f78
Amphistegina aucklandica	22	11
Amphistegina sp.	3	3
Bolivina semitruncata	1	
Cibicides notocenicus	6	
Cibicides mediocris	12	14
Cibicides vortex	6	4
Cibicides perforatus	1	
Cibicides temperatus	5	12
Cribrorotalia ornatissimum	7	2
Discorotalia tenuissima	1	
Elphidium gibsoni	17	39
Gaudryina convexa	9	9
Globocassidulina subglobosa	1	
Gyroidina zelandica		1
Notorotalia powelli	4	1
Melonis maorica	1	1
Quasibolivinella finlayi	2	1
Semivulvulina capitata	1	1
Stilostomella pomuligera	1	
Percent planktics	2	1